Three newly recorded species of Acerentomata (Hexapoda: Protura) from China, with analysis of DNA barcodes

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Abstract: Three newly recorded species in the order Acerentomata in Protura from China are described: *Filientomon duodecimsetosum* Nakamura, 2004, *Verrucoentomon anatoli* Shrubovych & Bernard, 2012 and *Verrucoentomon louisanne* Shrubovych & Bernard, 2012. The important morphological characters of Chinese specimens are described in detail. An updated key to Chinese *Verrucoentomon* species is provided. In addition, their DNA barcodes are sequenced and analyzed.

Key words: proturans; key; DNA barcodes; maxillary gland; taxonomy

中国蚖目的三新纪录种记述及其 DNA 条形码分析（六足总纲：原尾纲）

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摘要：记述蚖目 Acerentomata 原尾虫的 3 个中国新纪录种：十二毛线毛蚖 *Filientomon duodecimsetosum* Nakamura, 2004，安纳托利花腺蚖 *Verrucoentomon anatoli* Shrubovych & Bernard, 2012 和路易安妮花腺蚖 *Verrucoentomon louisanne* Shrubovych & Bernard, 2012。对中国标本的形态特征进行了详尽描述，绘制并拍摄了特征图，更新了花腺蚖属中国种类检索表。同时测定了新纪录种的 DNA 条形码序列，进行了遗传变异分析。

关键词：原尾虫；检索表；DNA 条形码；颚腺；分类

Introduction

There are 210 species of Protura belonging to 43 genera and 9 families recorded from China (Bai & Bu 2013a, 2013b; Bu *et al*. 2012, 2013, 2016; Bu & Wu 2012; Yin 1999) until now. The Protura fauna of Northeast China, however, are not yet well studied and only 34 species have been recorded (Bu *et al*. 2013, 2016). During the summer of 2014, we made an expedition to Heilongjiang Province and obtained a large number of proturan specimens. Among those materials, three proturan species were identified as new records for China, and are described and illustrated in this paper. In addition, their DNA barcodes are sequenced for

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Accepted 5 September 2016. Published 25 March 2017. Published online 17 March 2017.

① Corresponding author, E-mail: yxluan@sibs.ac.cn the first time.

Material and methods

Specimens were collected by Tullgren funnels. All specimens were mounted on slides in Hoyer's medium and dried at 60°C. Specimens were identified and drawn with the aid of a NIKON E600 phase contrast microscope. The photos were taken by digital camera Nikon DS-Ri2. All specimens are deposited in the Shanghai Entomological Museum (SEM), Shanghai Institute of Plant Physiology & Ecology, Chinese Academy of Sciences.

Abbreviations used in the text follow Bu and Yin (2007). Head setae and pores are marked according to Rusek *et al*. (2012). Arrangements of the taxa follow the system proposed by Yin (1999).

For the sequence of DNA barcodes, genomic DNA was extracted from each individual separately by a non-destructive method (Gao & Bu 2014). After the DNA extraction, the cuticles of proturans were retrieved and mounted on the slides as voucher specimens. We followed the experimental procedure for Protura described in Bai & Bu (2013b). The barcodes sequences are deposited in GenBank. The nucleotide composition and the genetic divergence based on Kimura-2-parameter (K2P) model were calculated using MEGA 6 (Tamura *et al*. 2013).

Taxonomy

Family Acerentomidae Silvestri, 1907

Genus *Filientomon* Rusek, 1974

Filientomon Rusek, 1974: 269. Type species: *Acerentulus lubricus takanawanus* Imadaté, 1956.

Diagnosis. The genus *Filientomon* Rusek, 1974 is characterized by the filiform foretarsal sensillum *t1*, normal setae *β1* and *δ4* on foretarsus, short maxillary gland with a dorsal helmet-like appendix, three and four pairs of *A*-setae on meso- and metanotum respectively, four setae on sternite VIII and a well-developed striate band.

Distribution. *Filientomon* with ten known species is distributed only in North Asia (China, Korea, Japan, Russian Far East and Siberia) and North America (USA) (Bu & Xie 2007). So far, only two species have been recorded in China: *F. takanawanum* (Imadaté, 1956) and *F. qianshanense* Bu & Xie, 2007.

1. ***Filientomon duodecimsetosum* Nakamura, 2004** (Figs. 1, 2, Table 1), new record to China

Filientomon duodecimsetosum Nakamura, 2004: 20.

Filientomon duodecimsetosum, Bu & Xie, 2007: 58.

Filientomon duodecimsetosum, Bu *et al*., 2014: 49.

Specimens examined. 10♀, nos. WHS4-1D, WHS4-9D, WHS4-3, WHS5-1D, WHS5-4-2, WHS7-1D, WHS7-11D, WHS7-13D, WHS7-3, WHS7-7, 5♂, nos. WHS4-4, WHS5-7D, WHS7-9D, WHS7-10D, WHS7-12D (SEM), **China**, Heilongjiang Province, Wudalianchi City, from soil samples of Wohu Mountain, 48°39'N, 126°02'E, elev. 459–493 m, 17-VIII-2014, coll. Wanjun CHEN, Chengwang HUANG, Yao MA, and Yunxia LUAN.

Diagnosis. *Filientomon duodecimsetosum* Nakamura, 2004 is characterized by the presence of six pairs of *A*-setae and nine pairs of *P*-setae on tergite II–VII, presence of *A1a* on tergite I, absence of seta *d6* on head, maxillary gland with two sensilla in different shapes, and the presence of seta *Pc* on sternites VI and VII.

Description. Adult body length 1300–1550 μm (*n* = 15), body yellow-brown color (Fig. 2A).

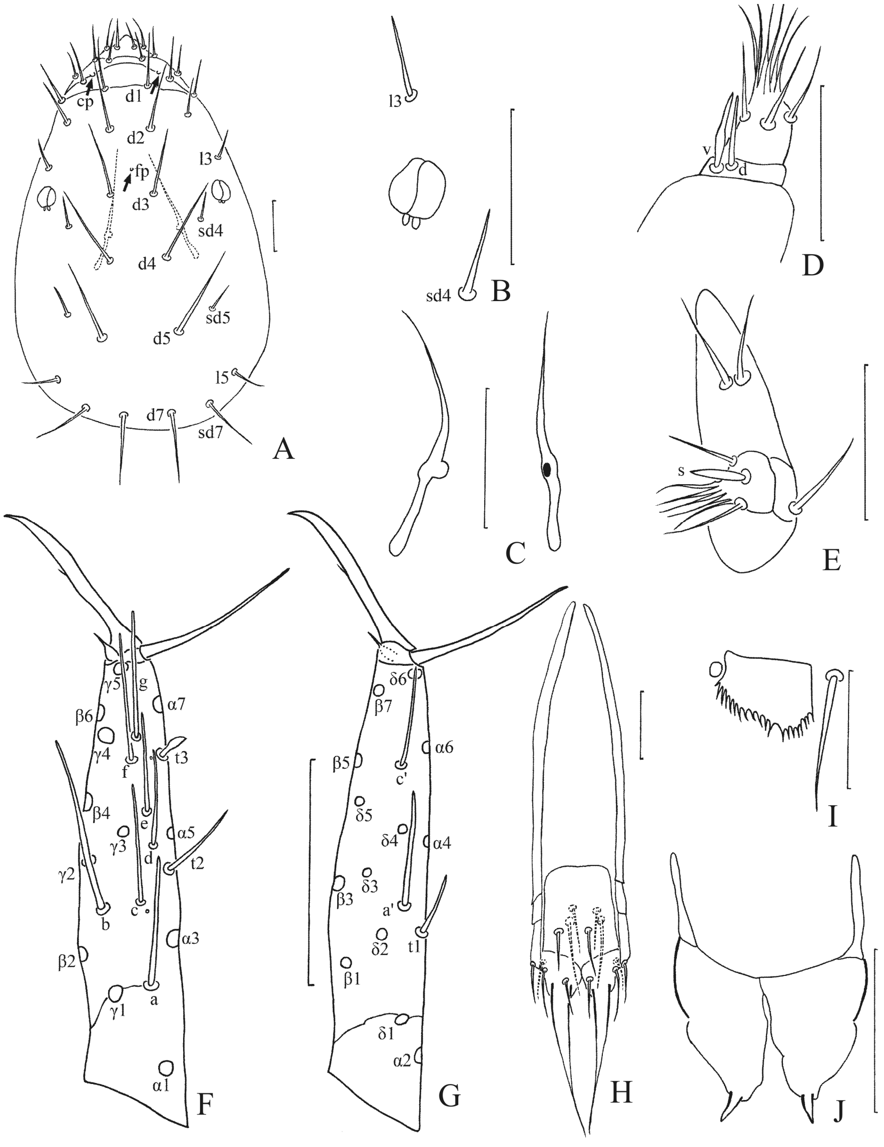

Figure 1. *Filientomon duodecimsetosum* Nakamura, 2004. A. Head, dorsal view (*cp* = clypeal pore, *fp* = frontal pore); B. Pseudoculus; C. Canal of maxillary gland; D. Maxillary palpus; E. Labial palpus; F. Foretarsus, exterior view; G. Foretarsus, interior view; H. Male quama genitalis; I. Comb; J. Female quama genitalis. Arrows indicate pores. Scale bars = 50 μm (F, G); 20 μm (others). Fig. A from specimen WHS4-3, Fig. H from specimen WHS4-4, Fig. J from specimens WHS7-3, others from specimen WHS7-1D.

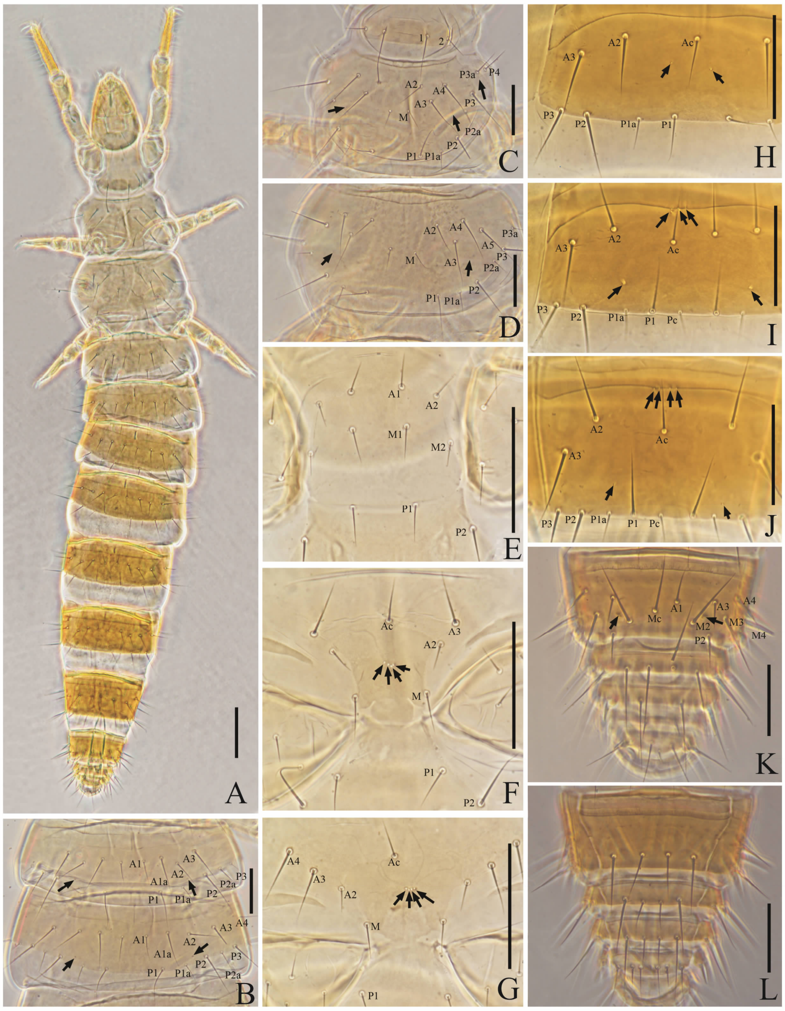

Figure 2. *Filientomon duodecimsetosum* Nakamura, 2004. A. Habitus; B. Tergites I–II; C. Pronotum and mesonotum; D. Metanotum; E. Prosternum; F. Mesosternum; G. Metasternum; H. Sternite V; I. Sternite VI; J. Sternite VII; K. Tergites VIII–XII; L. Sternites VIII–XII. Arrows indicate pores. Scale bars = 100 µm (A), 50 µm (others). Figs. B, K and L from specimen WHS-7-7, others from specimen WHS-4-4.

Head (Fig. 1A). Ovate, length 150–160 µm, width 100–110 µm. Setae *d6* absent, *sd4* and *sd5* short, 13–15 µm. Clypeal pore *cp* and frontal pore *fp* present. Pseudoculus round, length 8–10 µm, with short posterior extension, PR = 15–20 (Fig. 1B). Maxillary gland small, calyx with one helmet-like dorsal appendix, and short posterior dilation, posterior filament length 15–18 µm, CF = 8.3–10.7 (Fig. 1C). Maxillary palpus with two subequal sensilla, dorsal one straight, ventral one slightly broad in middle, both 8–9 µm length (Fig. 1D) Labial palpus well-developed, with tuft and one lanceolate basal sensillum (6 µm) (Fig. 1E).

Foretarsus (Figs. 1F, G). Length 102–115 µm, claw length 36–42 µm, with one inner tooth, TR = 2.6–2.9; empodium length 5 µm, EU = 0.12–0.14. Dorsal sensilla *t1* filiform, *t2* slender and long (22 µm), BS = 0.62–0.65, *t3* lanceolate and short. Exterior sensilla *a* slender (31 µm), *b* broad and long, reaching base of *g*, *c* slender, *d* filiform, close to *e*, *e* short, *f* and *g* filiform and subequal in length. Interior sensilla *a′* broad (26 µm), surpassing base of *δ5*, *b′* absent, *c′* slender and short, not surpassing base of claw, just reach base of *δ6*. Relative length of sensilla: $b < a < (f = g) < c < a' < e < (d = t2 = c') < t1 < t3$. Setae *β1* and *δ4* normal. Pores close to sensilla *c* and *t3* present. Length of middle tarsus 50–55 µm, claw length 20–23 µm. Length of hind tarsus 60 µm, claw length 25 µm.

Thorax. Thoracic chaetotaxy given in Table 1. Setae *1* and *2* on pronotum 45–47 µm and 23–27 µm length respectively (Fig. 2C). Mesonotum and metanotum with eight pairs of *P*-setae, accessory setae normal, 20–26 µm in length, seta *M* 21–25 µm; setae *P1*, *P1a* and *P2* on mesonotum 42–46 µm, 20–26 µm and 51–60 µm respectively (Figs. 2C, D). Prosternum with two pairs of anterior seta, and setae *A2* and *M2* sensilliform (Fig. 2E). Mesosternum and metasternum with five and seven *A*-setae respectively, and setae *A2* on mesosternum and metasternum sensilliform (Figs. 2F, G). Pronotum without pores. Mesonotum with pores *sl* and *al* and metanotum with *sl* only. Prosternum without pores, meso- and metanota each with three or four middle pores in one group (Figs. 2F, G).

Table 1. Adult chaetotaxy of *Filientomon duodecimsetosum* Nakamura, 2004

Segment		Dorsal		Ventral	
		Formula	Setae	Formula	Setae
Th.	I	4	1, 2	$\frac{4+4}{6}$	A1, 2, M1, 2 P1, 2, 3
	II	$\frac{8}{16}$	A2, 3, 4, M P1, 1a, 2, 2a, 3, 3a, 4, 5	$\frac{5+2}{4}$	Ac, 2, 3, M P1, 2
	III	$\frac{10}{16}$	A2, 3, 4, 5, M P1, 1a, 2, 2a, 3, 3a, 4, 5	$\frac{7+2}{4}$	Ac, 2, 3, 4, M P1, 2
Abd.	I	$\frac{8}{14}$	A1, 1a, 2, 3 P1, 1a, 2, 3, 3a, 4, 5	$\frac{3}{4}$	Ac, 2 P1, 1a
	II–III	$\frac{12}{18}$	A1, 1a, 2, 3, 4, 5 P1, 1a, 2, 2a, 3, 3a, 4, 4a, 5	$\frac{5}{5}$	Ac, 2, 3 Pc, 1a, 2
	IV–V	$\frac{12}{18}$	A1, 1a, 2, 3, 4, 5 P1, 1a, 2, 2a, 3, 3a, 4, 4a, 5	$\frac{5}{8}$	Ac, 2, 3 P1, 1a, 2, 3
	VI	$\frac{12}{18}$	A1, 1a, 2, 3, 4, 5 P1, 1a, 2, 2a, 3, 3a, 4, 4a, 5	$\frac{5}{9}$	Ac, 2, 3 Pc, 1, 1a, 2, 3
	VII	$\frac{12}{18}$	A1, 2, 3, 4, 4a, 5 P1, 1a, 2, 2a, 3,3a, 4, 4a, 5	$\frac{5}{9}$	Ac, 2, 3 Pc, 1, 1a, 2, 3
	VIII	$\frac{8}{15}$	A1, 3, 4, 5 Mc, 2, 3, 4, P2, 3, 4, 5	4	1, 2
	IX	14	1, 2, 3, 3a, 4, 4a, 5	4	1, 2
	X	10	1, 2, 3, 4, 5	4	1, 2
	XI	6	1, 3, 4	6	1, 2, 3
	XII	9		6	

Abdomen. Abdominal chaetotaxy given in Table 1. Tergite I with four pairs of anterior setae (*A1*, *A1a*, *A2*, *A3*) (Fig. 2B). Tergites II–VII with six pairs of anterior setae and nine pairs of posterior setae (Fig. 2B), II–VI with seta *A1a*, VII with seta *A4a*. Accessory setae on tergites I–VII normal. Tergite VIII with seta *Mc* (Fig. 2K). Sternites II–VII each with five *A*-setae (Fig. 2J), II–III each with five *P*-setae, IV–V each with eight *P*-setae, VI–VII each with nine *P*-setae (Figs. 2H–J). Sternite VIII with four setae (Fig. 2L). Anterior part of tergite and sternite VIII with several irregular teeth.

Tergites II–V with pores *psm* and *al*, VI–VII with pores *psm*, *al* and *psl*, I and VIII with pores *psm* only, IX–XI without pores, XII with single medial pore. Sternite I with single medial pore, II–V each with two medial pores (Fig. 2), VI and VII each with a pair of pores lateroanterior to *P1a* and three or four pores anterior to *Ac* in a transverse line (Figs. 2I, J). Sternites VIII–XI without pores, XII with 1+1 *al* pores.

Abdominal appendages I, II, III with 2, 1, 1 segments and 4, 2, 2 setae respectively. On appendages II and III, subapical setae 15–16 μm, apical setae 14–15 μm in length. Striate band on abdominal segment VIII well-developed (Figs. 2K, L). Posterior margin of comb on abdomen VIII rounded and protruding distinctly backward, with 18–20 teeth (Fig. 1I). Male squama genitalis with four pairs of dorsal setae and three pairs of ventral setae (Fig. 1H). Female squama genitalis with short basal apodeme and subuliform acrostyli (Fig. 1J)

Chaetal variability. The thoracic chaetotaxy is relatively stable but abdominal chaetotaxy is fairly variable. Among 15 adult specimens checked, the following variations are observed: on tergite I, asymmetrical absence of *A2* (5 specimens) or asymmetrical presence of *A5* (1 specimens); on tergites II–VII, asymmetrical absence of *A2* or *A3* (10 specimens), or asymmetrical present of one *A*-setae (4 specimens); on tergite VIII, asymmetrical absence of *A2* (1 specimens), or absence of *Mc* (2 specimens); on tergite X, asymmetrical absence of *A2a* (1 specimens); on sternites II–III, asymmetrical absence of *A1* or *A2* (3 specimens); on sternite III, with 6 *P*-setae (3 specimens); on sternite IV, asymmetrical absence of *A2* (1 specimens); on sternite V, asymmetrical absence of *P3* (1 specimens), presence of one setae on right side (1 specimens); on sternite VI, with 6 or 7 setae (8 specimens); on sternite VII, asymmetrical absence of *P2* (1 specimens), absence of *Pc* (1 specimens).

Distribution. China (Heilongjiang); Russia (Khabarovsk).

Remarks. *Filientomon duodecimsetosum* Nakamura, 2004 was first described from Russian Far East based on only 1 male and 1 maturi junior. Because of the limited material, its chaetotaxy on tergite I, sternite V and VI, and the pores on the body were not well determined (Nakamura 2004). We give a complete description and confirm all chaetotaxy and pores on the body. In addition, the specimens we have examined have some minor differences compared to the types: mesonotum with pores *sl* and *al* vs. with only *al* in types; metanotum with pores *sl* only vs. with pores *sl* and *al* in types; sternite II with two pores vs. with one pore in types; sternite XI with six setae vs. with four setae in types.

Family Nipponentomidae Yin, 1996

Genus *Verrucoentomon* Rusek, 1974

Verrucoentomon Rusek, 1974: 270. Type species: *Acerella kawakatsui* Imadaté, 1964.

Diagnosis. The genus *Verrucoentomon* is characterized by the presence of a large, distinctly granulated calyx on the maxillary gland; foretarsal sensillum *t1* filiform, position of sensillum *d* on foretarsus close to base of *e*, and both of mesonotum and metanotum each with three pairs of *A*-setae.

Distribution. *Verrucoentomon* with 13 known species, mostly distributed in North Asia (China, Korea, Japan, Russian Far East and Siberia) and North America (USA), with only one species reported from Central Europe (Shrubovych & Bernard 2012). So far, only two species were recorded in China: *V. yushuense* Yin, 1980 and *V. xinjiangense* Yin, 1987.

2. ***Verrucoentomon anatoli* Shrubovych & Bernard, 2012** (Fig. 3, Table 2), new record to China

Verrucoentomon anatoli Shrubovych & Bernard, 2012: 628.

Specimens examined. 2♀ (nos. WHS4-14D, WHS7-4), 2♂ (nos. WHS4-10D, WHS4-11D), 1 maturus junior (no. WHS5-3-1), 1 larva II (no. WHS6-3-1) (SEM), **China**, Heilongjiang Province, Wudalianchi City, from soil samples of Wohu Mountain, 48°39'N, 126°02'E, elev. 459–493 m, 17-VIII-2014, coll. Wanjun CHEN, Chengwang HUANG, Yao MA, and Yunxia LUAN.

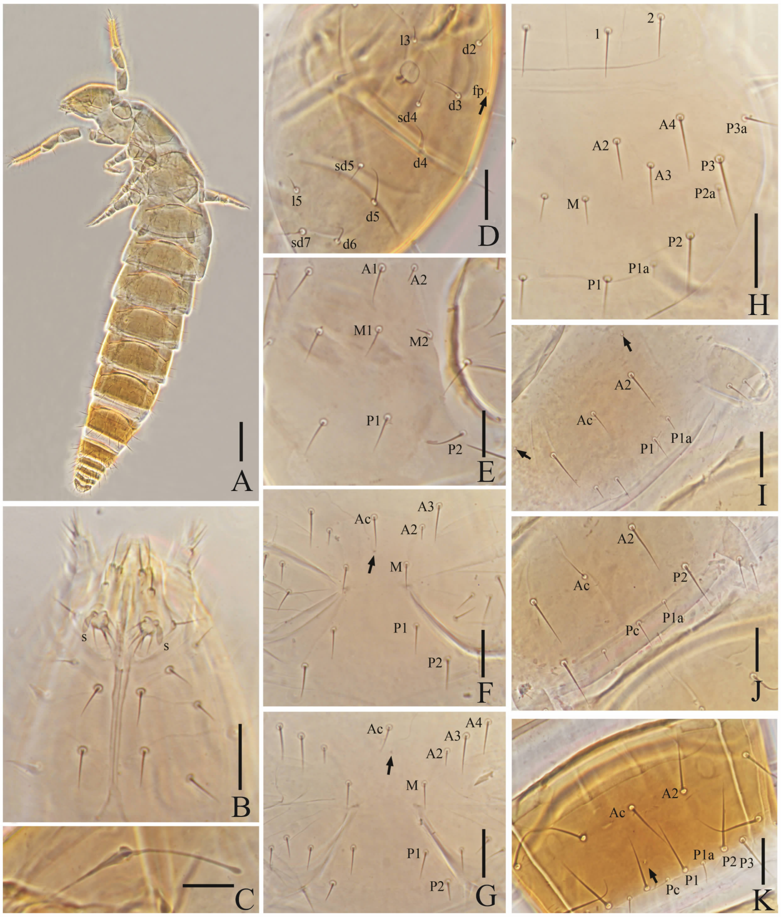

Figure 3. *Verrucoentomon anatoli* Shrubovych & Bernard, 2012. A. Habitus; B. Ventral side of head; C. Maxillary gland; D. Head, lateral dorsal view; E. Prosternum; F. Mesosternum; G. Metasternum; H. Pronotum and mesonotum, right side; I. Sternite I; J. Sternite II; K. Sternite VII. Arrows indicate pores. Scale bars = 100 µm (A), 20 µm (others). Figs. A, C, I–K from specimen WHS7-4, and others from specimen WHS5-3-1.

Diagnosis. *Verrucoentomon anatoli* Shrubovych & Bernard, 2012 is characterized by the short, broad shape of foretarsal sensilla *c* and *e*, presence of seta *d6* on head, presence of *P1a* on tergites I–VI, and accessory setae on the body short and sensilliform.

Description. Adult body length 1250 μm (*n* = 4), body yellow color (Fig. 3A).

Head (Figs. 3B, D). Ovate, length 150 μm, width 80 μm, with short setae. Setae *d6* present, setae *l3*, *sd4* and *sd5* sensilliform. Clypeal pore *cp* and frontal pore *fp* present. Pseudoculus small, length 8 μm, with short posterior extension, PR = 15 (Fig. 3D). Maxillary gland large, calyx with lateral racemose appendices and one helmet-like dorsal appendix, and bilobed posterior dilation, posterior filament length 45 μm, CF = 2.9 (Fig. 3C). Maxillary palpus with slender, subequal sensilla, labial palpus well-developed with broad basal sensillum (Fig. 3B). Granulation on inner margin of labium distinct.

Table 2. Adult chaetotaxy of *Verrucoentomon anatoli* Shrubovych & Bernard, 2012

Segment		Dorsal		Ventral	
		Formula	Setae	Formula	Setae
Th.	I	4	1, 2	4+4	A1, 2, M1, 2
				6	P1, 2, 3
	II	8	A2, 3, 4, M	5+2	Ac, 2, 3, M
		16	P1, 1a, 2, 2a, 3, 3a, 4, 5	4	P1, 2
	III	8	A2, 3, 4, M	7+2	Ac, 2, 3, 4, M
		16	P1, 1a, 2, 2a, 3, 3a, 4, 5	4	P1, 2
Abd.	I	6	A1, 2, 5	3	Ac, 2
		12	P1, 1a, 2, 2a, 3, 4	4	P1, 1a
	II	10	A1, 2, 3, 4, 5	3	Ac, 2
		16	P1, 1a, 2, 2a, 3, 4, 4a, 5	5	Pc, 1a, 2
	III	10	A1, 2, 3, 4, 5	3	Ac, 2
		16	P1, 1a, 2, 2a, 3, 4, 4a, 5	6	P1, 1a, 2
	IV–VI	10	A1, 2, 3, 4, 5	3	Ac, 2
		16	P1, 1a, 2, 2a, 3, 4, 4a, 5	8	P1, 1a, 2, 3
	VII	8	A2, 3, 4, 5	3	Ac, 2
		16	P1, 1a, 2, 2a, 3, 4, 4a, 5	9	Pc, 1, 1a, 2, 3
	VIII	6	A1, 4, 5	4	1, 2
		15	Mc, 2, 3, 4, P2, 3, 4, 5	2	1a
	IX	12	1, 1a, 2, 2a, 3, 4	4	1, 2
	X	10	1, 2, 2a, 3, 4	4	1, 2
	XI	6	1, 3, 4	6	1, 2, 3
	XII	9		6	

Foretarsus. Length 88 μm, claw length 25 μm, with one inner tooth, TR = 3.5; empodium length 6 μm, EU = 0.24. Dorsal sensillum *t1* filiform, *t2* slender and long, *t3* leaf-like, BS = 0.76; exterior sensillum *a*, *b* and *g* parallel-sided, *c* and *e* short and broad, *d* and *f* slender and long. Interior sensilla *a'* slightly broadened, *b'* absent, *c'* slender and surpassing base of claw. Relative length of sensilla: *t3* < (*c* = *e*) < *a* < *g* < *t1* < (*b* = *a'*) < *c'* < *t2* < *d* < *f*. Pores close to sensilla *c* and *t3* present. Length of middle tarsus 45 μm, claw length 15 μm. Length of hind tarsus 48 μm, claw length 18 μm.

Thorax. Thoracic chaetotaxy given in Table 2. Mesonotum and metanotum with eight pairs of *P*-setae, accessory setae short sensilliform, 5 μm in length; setae *P1*, *P1a* and *P2* on mesonotum 15 μm, 5 μm and 27 μm respectively (Fig. 3H). Prosternum with two pairs of anterior seta, and setae *A2* and *M2* sensilliform (Fig. 3E). Mesosternum and metasternum with five and seven *A*-setae respectively, and setae *A2* on mesosternum and metasternum sensilliform (Figs. 3F, G). Pronotum and prosternum without pores. Mesonotum and metanotum with pores *sl* and *al*. Mesosternum and metasternum each with a single pore posterior to *Ac* (Figs. 3F, G).

Abdomen. Abdominal chaetotaxy given in Table 2. Accessory setae on tergites I–VII sensilliform, 10–11 μm. Tergites I and VIII with pores *psm* only, II–VI with pores *psm* and *al*, VII with pores *psm*, *al* and *psl*, IX–XI without pores and XII with single medial pore. Sternites I with one pair of anterolateral pores, II–III without pores (Figs. 3I, J), IV–VII with single medial pore, anterior to *P1* setae (Fig. 3K), VIII–XI without pores, XII with 1+1 *al* pores.

Abdominal appendages I, II, III with 2, 1, 1 segments and 4, 2, 2 setae respectively. On appendages II and III, subapical setae 15 μm, apical setae 11–12 μm in length (Figs. 3I, J). Striate band on abdominal segment VIII well-developed, Pore *psm* on tergite VIII with several accompanying teeth. Comb on abdomen VIII rectangular, with 12–14 teeth. Female squama genitalis short, with stumpy acrostyli.

Distribution. China (Heilongjiang); Russia (Siberia).

Remarks. The shape and length of foretarsal sensilla and body chaetotaxy of Chinese materials is almost the same as the type materials described by Shrubovych and Bernard (2012). The differences are the length of accessory setae on tergites I–VII, 10–11 μm in Chinese materials vs. 4 μm on I–VI and 8 μm on VII in types, the position of *a'* as same level to *t2* in Chinese materials vs. distinctly higher than *t2* in types, and the presence of *Pc* seta on sternite VII vs. absent in types.

3. ***Verrucoentomon louisanne*** **Shrubovych & Bernard, 2012** (Fig. 4, Table 3), new record to China

Verrucoentomon louisanne Shrubovych & Bernard, 2012: 632.

Verrucoentomon louisanne, Bu *et al.*, 2014: 45.

Specimens examined. 3♀ (nos. DZH2-11D, DZH2-13, DZH2-15), 1 Larva II (no. DZH2-14) (SEM), **China,** Heilongjiang Province, Wudalianchi City, from the soil sample under larch in Dazhanhe National Forest Park, 48°41.726'N, 127°40.556'E, elev. 327 m, 18-VIII-2014. coll. Wanjun CHEN, Chengwang HUANG, Yao MA, and Yunxia LUAN.

Diagnosis. *Verrucoentomon louisanne* Shrubovych & Bernard, 2012 is characterized by the broadened foretarsal sensilla *b*, *d*, and *a'*, sensillum *c* slender and shorter than *b*, absence of seta *d6* on head, absence of *P1a* on tergites I–VI, presence of seta *Pc* on sternite VII, possession of 12 and 8 setae on tergites IX and X respectively, and accessory setae on the body short and sensilliform.

Description. Adult body length 1300 μm (*n* = 3), body yellow colored (Fig. 4A).

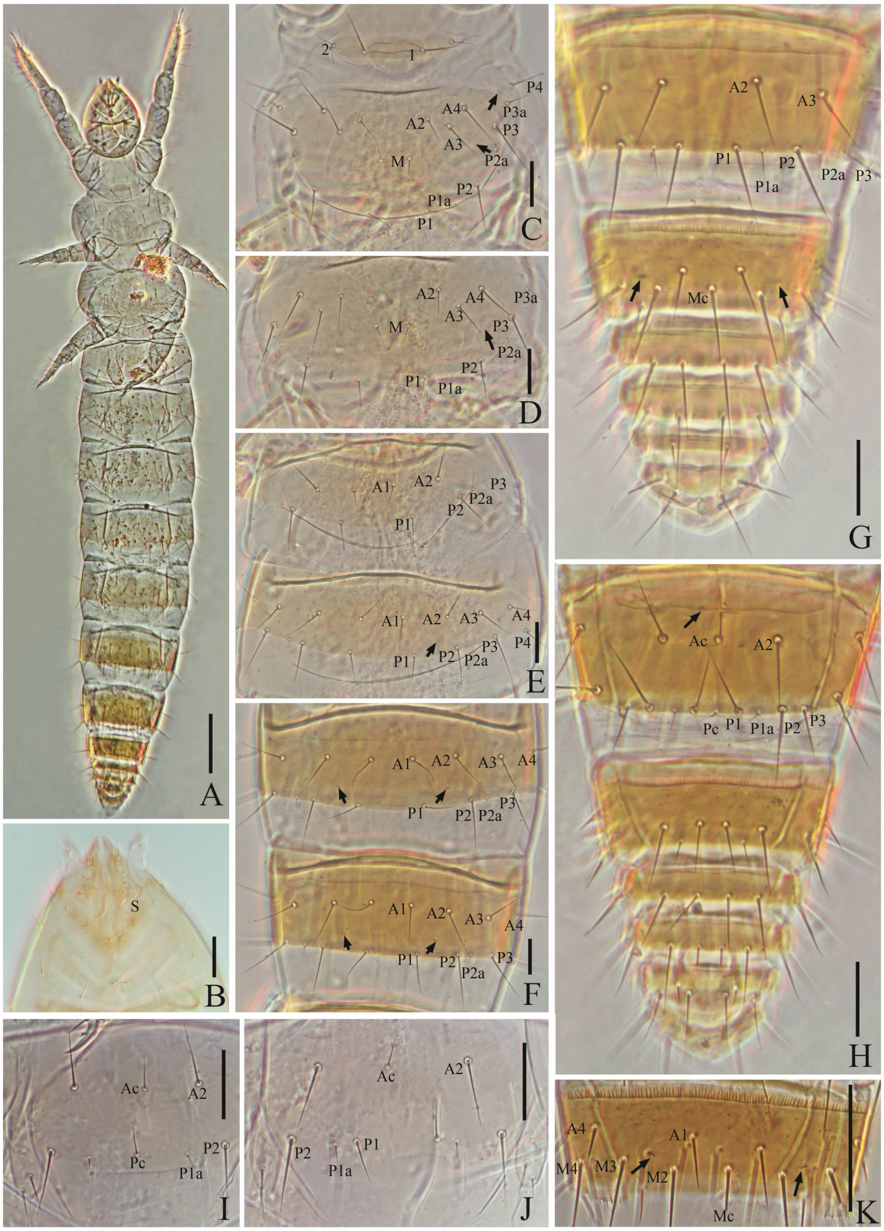

Figure 4. *Verrucoentomon louisanne* Shrubovych & Bernard, 2012. A. Habitus; B. Ventral side of head; C. Pronotum and mesonotum; D. Metanotum; E. Tergites I–II; F. Tergites V–VI; G. Tergites VII–XII; H. Sternites VII–XII. I. Sternite I; J. Sternite II; K. Tergite VIII. Arrows indicate pores. Scale bars = 100 μm (A), 20 μm (others). Figs. G and H from specimen DZH2-15, Fig. K from specimens DZH-11D, others from specimen DZH2-13.

Head (Fig. 4B). Ovate, length 135–140 μm, width 90–100 μm. Setae *d6* absent. Clypeal pore *cp* and frontal pore *fp* present. Pseudoculus small, length 7–8 μm, with short posterior extension, PR = 15–17. Maxillary gland with broad distinctly granulated calyx, posterior filament length 25 µm, CF = 5.4–5.6. Maxillary palpus with slender, subequal sensilla, 7–8 µm. Labial palpus well-developed with broad basal sensillum (Fig. 4B). Granulation on inner margin of labium distinct.

Foretarsus. Length 85 µm, claw length 30 µm, with one inner tooth, TR = 2.5–2.8; empodium length 5 µm, EU = 0.17–0.18. Dorsal sensillum *t1* filiform, *t2* slender and long, *t3* leaf-like, BS = 0.77–0.81; exterior sensillum *a* slender, *b* and *g* broadened distally, *c* slightly shorter than *b*, *d* closer to *e* than to *c*, *e* short, *f* slender and extremely long. Interior sensilla *a'* distinctly broad, *b'* absent, *c'* slender and far surpassing base of claw. Relative length of sensilla: $t3 < (e = g) < t1 < c < b < d < a' < a < (c' = t2) < f$. Length of middle tarsus 43–45 µm, claw length 18 µm. Length of hind tarsus 46–50 µm, claw length 20 µm.

Table 3. Adult chaetotaxy of *Verrucoentomon louisanne* Shrubovych & Bernard, 2012

Segment		Dorsal		Ventral	
		Formula	Setae	Formula	Setae
Th.	I	4	1, 2	$\frac{4+4}{6}$	A1, 2, M1, 2 P1, 2, 3
	II	$\frac{8}{16}$	A2, 3, 4, M P1, 1a, 2, 2a, 3, 3a, 4, 5	$\frac{5+2}{4}$	Ac, 2, 3, M P1, 2
	III	$\frac{8}{16}$	A2, 3, 4, M P1, 1a, 2, 2a, 3, 3a, 4, 5	$\frac{7+2}{4}$	Ac, 2, 3, 4, M P1, 2
Abd.	I	$\frac{6}{10}$	A1, 2, 5 P1, 2, 2a, 3, 4	$\frac{3}{4}$	Ac, 2 P1, 1a
	II	$\frac{10}{14}$	A1, 2, 3, 4, 5 P1, 2, 2a, 3, 4, 4a, 5	$\frac{3}{5}$	Ac, 2 Pc, 1a, 2
	III	$\frac{10}{14}$	A1, 2, 3, 4, 5 P1, 2, 2a, 3, 4, 4a, 5	$\frac{3}{6}$	Ac, 2 P1, 1a, 2
	IV–VI	$\frac{10}{14}$	A1, 2, 3, 4, 5 P1, 2, 2a, 3, 4, 4a, 5	$\frac{3}{8}$	Ac, 2 P1, 1a, 2, 3
	VII	$\frac{8}{16}$	A2, 3, 4, 5 P1, 1a, 2, 2a, 3,4, 4a, 5	$\frac{3}{9}$	Ac, 2 Pc, 1, 1a, 2, 3
	VIII	$\frac{6}{15}$	A1, 4, 5 Mc, 2, 3, 4, P2, 3, 4, 5	$\frac{4}{2}$	1, 2 1a
	IX	12	1, 1a, 2, 2a, 3, 4	4	1, 2
	X	8	1, 2, 3, 4	4	1, 2
	XI	6	1, 3, 4	6	1, 2, 3
	XII	9		6	

Thorax. Thoracic chaetotaxy is given in Table 3. Setae *P1*, *P1a* and *P2* on mesonotum 25 µm, 5 µm and 36 µm respectively (Fig. 4C). Prosternum with two pairs of anterior seta, and setae *A2* and *M2* sensilliform. Mesosternum and metasternum with five and seven *A*-setae respectively, and setae *A2* on mesosternum and metasternum sensilliform. Pronotum and prosternum without pores. Mesonotum and pores *sl* and *al*, metanotum with *sl* pores only (Figs. 4C, D). Mesosternum and metasternum each with a single pore posterior to *Ac*.

Abdomen. Abdominal chaetotaxy given in Table 3. Setae *P1a* absent on tergites I–VI (Figs. 4E, F). Sternite VII with seta *Pc* (Fig. 4H). Accessory setae on tergites I–VII sensilliform and 7–8 µm, on tergite VII normal and 12 µm. Tergites I and VIII with pores *psm* only, II–VI with pores *psm* and *al*, VII with pores *al* only, IX–XI without pores and XII with single medial pore (Figs. 4E, F, G). Sternites I without pores, II–V each with single median pore, VI without pores, VII with a medial pore, anterior to *Ac* on connecting line, VIII–XI without pores, XII with 1+1 *al* pores (Fig. 4H).

Abdominal appendages I, II, III with 2, 1, 1 segments and 4, 2, 2 setae respectively. On appendages II and III, subapical setae 24 µm, apical setae 21 µm in length (Figs. 4I, J). Striate band on abdominal segment VIII well-developed. Tergite and sternite VIII with an anterior transverse row of small teeth. Pore *psm* on tergite VIII with several accompanying teeth (Fig. 4K). Comb on abdomen VIII rectangular, with 9–12 teeth. Female squama genitalis bipartite acrostyli.

Distribution. China (Heilongjiang); Russia (Far East).

Remarks. *Verrucoentomon louisanne* was found only from the type locality (Russian Far East) before this study (Bu *et al.* 2014). The morphology of Chinese materials is nearly the same as the type materials described by Shrubovych and Bernard (2012). The new distribution in Wudalianchi City of Heilongjiang Province in northeast China is about 700 km, far from the type locality. Therefore, this species is probably widely distributed through the Russian Far East and Northeast China.

Key to Chinese *Verrucoentomon* species

1. Meso- and metanota without *P2a'* setae ··· 2
-. Meso- and metanota with *P2a'* setae ··· *V. xinjiangense* Yin
2. Tergites I–VI without *P1a* setae ··· 3
-. Tergites I–VI with *P1a* setae ··· *V. anatoli* Shrubovych & Bernard
3. Sternite I with two *P*-setae, sternite VII without *Pc* seta ··· *V. yushuense* Yin
-. Sternite I with four *P*-setae, sternite VII with *Pc* seta ··· *V. louisanne* Shrubovych & Bernard

DNA barcodes and genetic divergences

The standard DNA barcodes (COI gene) from five individuals (voucher specimen nos. WHS4-1D, WHS5-1D, WHS5-7D, WHS5-8D, and WHS7-9D) of *F. duodecimsetosum*, five individuals (voucher specimen nos. WHS4-10D, WHS4-11D, WHS4-12D, WHS4-15D, WHS4-16D) of *V. anatoli*, and one individual (voucher specimen no. DZH2-11D) of *V. louisanne* were sequenced and deposited in GenBank. The accession numbers as KX620016–KX620026.

The sequences each are composed of 658 base pairs. The average nucleotide compositions are A = 23.7%, T = 41.4%, C = 16.8% and G = 18.1% for *F. duodecimsetosum*; A = 26%, T = 40.6%, C = 16.6% and G = 16.9% for *V. anatoli*, as well as A = 26.3%, T = 42.1%, C = 15.3% and G = 16.3% for *V. louisanne*.

The K2P genetic divergence of nucleotides for barcode sequences are 0-0.61% between five individuals of *F. duodecimsetosum*, which were collected from three soil samples (WHS4, WHS5 and WHS7) of the same mountain (Wohu Mt.). There is not any difference in nucleotide in barcode sequences of the five individuals of *V. anatoli* collected from the same soil sample (WHS4). In comparison with the other species of the same genus, the K2P divergences are 20.63-20.84% between five *F. duodecimsetosum and* one *F. takanawanum* (GenBank Accession no. HQ882822), as well as 21% between *V. anatoli* and *V. louisanne*.

Acknowledgements

We give our cordial gratitude to Dr. Wanjun CHEN, Mr. Chengwang HUANG and Dr. Yao MA for their help during the collection of specimens, and Mr. Rongdong XIE for his instruction in identification. This study was supported by the National Natural Science Foundation of China (31471958, 31272298), the Youth Innovation Promotion Association of the CAS (2013183), and the Open Project of Key Laboratory of Insect Developmental and Evolutionary Biology, CAS (2009DP17321409).

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